



US009276571B2

(12) **United States Patent**  
**Yang et al.**

(10) **Patent No.:** **US 9,276,571 B2**  
(45) **Date of Patent:** **\*Mar. 1, 2016**

(54) **SYSTEMS AND METHODS FOR DRIVING TRANSISTORS WITH HIGH THRESHOLD VOLTAGES**

G09G 2320/232; G09G 2320/0252; G11C 16/02; G11C 16/08; H03K 17/16; H03K 17/102; H03K 17/18; H03K 19/00361; H03K 5/08

(71) Applicant: **ON-BRIGHT ELECTRONICS (SHANGHAI) CO., LTD.**, Shanghai (CN)

USPC ..... 327/108, 109, 110  
See application file for complete search history.

(72) Inventors: **Jiqing Yang**, Shanghai (CN); **Meng Li**, Shanghai (CN); **Qiang Luo**, Shanghai (CN); **Lieyi Fang**, Shanghai (CN)

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,543,740 A 8/1996 Wong  
7,791,374 B2 9/2010 Choi et al.  
8,648,630 B2 \* 2/2014 Yang et al. .... 327/109

(73) Assignee: **On-Bright Electronics (Shanghai) Co., Ltd.**, Shanghai (CN)

FOREIGN PATENT DOCUMENTS

(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

CN 101123842 2/2008  
TW 201020714 6/2010  
WO WO 2006-101139 3/2008

This patent is subject to a terminal disclaimer.

OTHER PUBLICATIONS

Taiwan Patent Office, Office Action mailed Jan. 23, 2014, in Application No. 100143180.

Chinese Patent Office, Office Action mailed Sep. 29, 2014, in Application No. 201110317087.1.

(21) Appl. No.: **14/106,660**

(22) Filed: **Dec. 13, 2013**

\* cited by examiner

(65) **Prior Publication Data**

US 2014/0103970 A1 Apr. 17, 2014

**Related U.S. Application Data**

(63) Continuation of application No. 13/297,085, filed on Nov. 15, 2011, now Pat. No. 8,648,630.

*Primary Examiner* — John Poos

(74) *Attorney, Agent, or Firm* — Jones Day

(30) **Foreign Application Priority Data**

Oct. 12, 2011 (CN) ..... 2011 1 0317087

(57) **ABSTRACT**

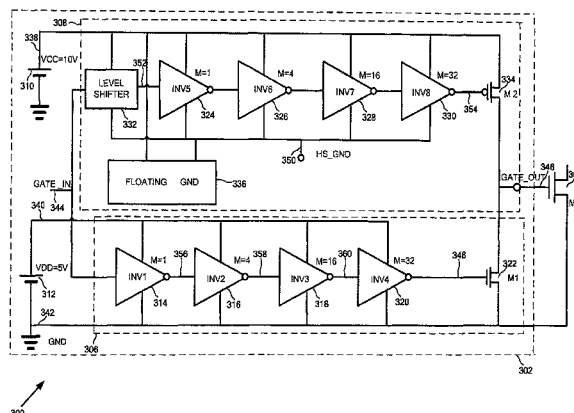
System and method are provided for driving a transistor. The system includes a floating-voltage generator, a first driving circuit, and a second driving circuit. The floating-voltage generator is configured to receive a first bias voltage and generate a floating voltage, the floating-voltage generator being further configured to change the floating voltage if the first bias voltage changes and to maintain the floating voltage to be lower than the first bias voltage by a first predetermined value in magnitude. The first driving circuit is configured to receive an input signal, the first bias voltage and the floating voltage. The second driving circuit is configured to receive the input signal, a second bias voltage and a third bias voltage, the first driving circuit and the second driving circuit being configured to generate an output signal to drive a transistor.

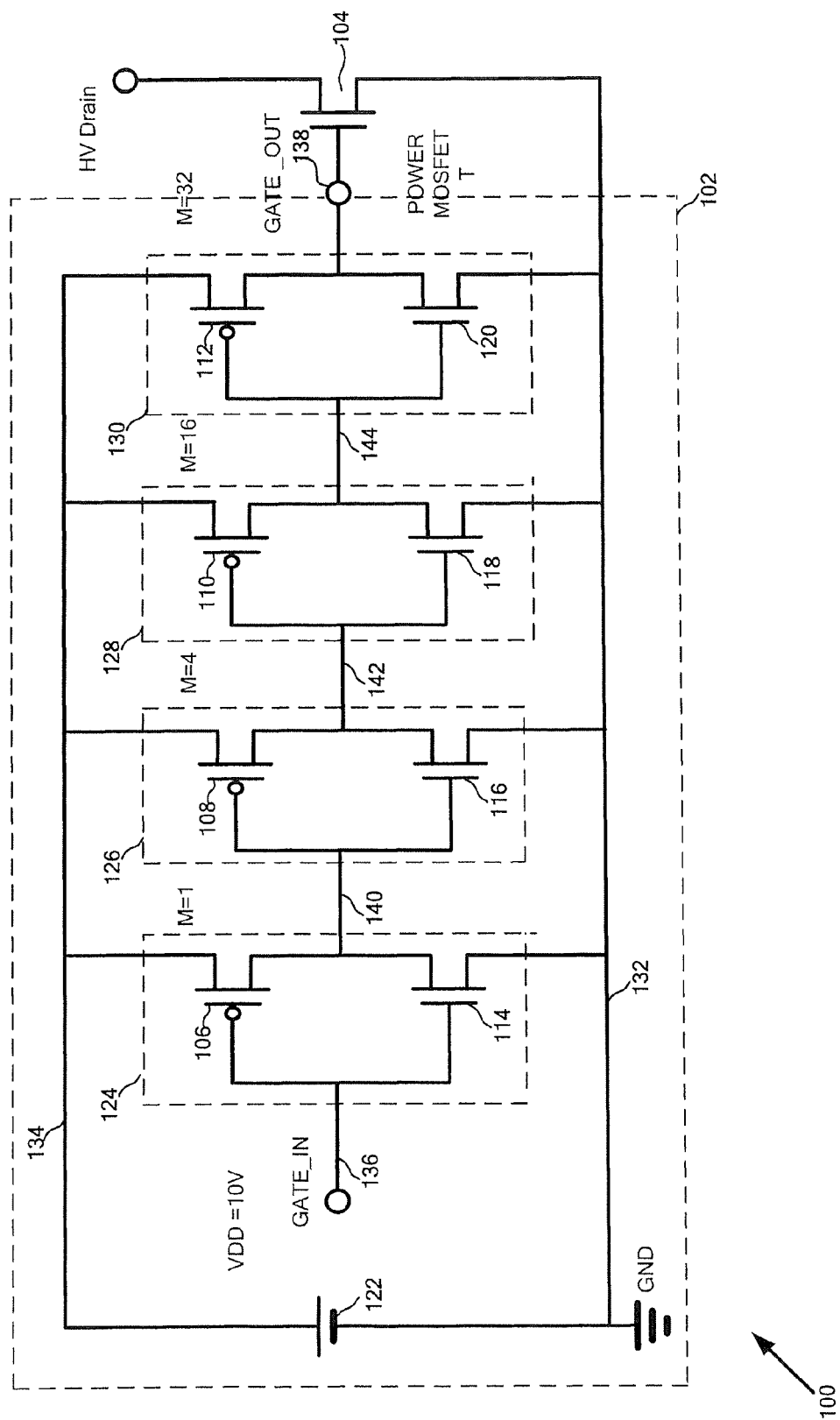
(51) **Int. Cl.**  
**H03K 17/30** (2006.01)  
**H03K 17/06** (2006.01)

(52) **U.S. Cl.**  
CPC ..... **H03K 17/302** (2013.01); **H03K 17/063** (2013.01); **H03K 2217/0081** (2013.01)

(58) **Field of Classification Search**  
CPC ..... G09G 2310/0289; G09G 2320/0214;

**14 Claims, 8 Drawing Sheets**





**Figure 1**  
(Prior Art)

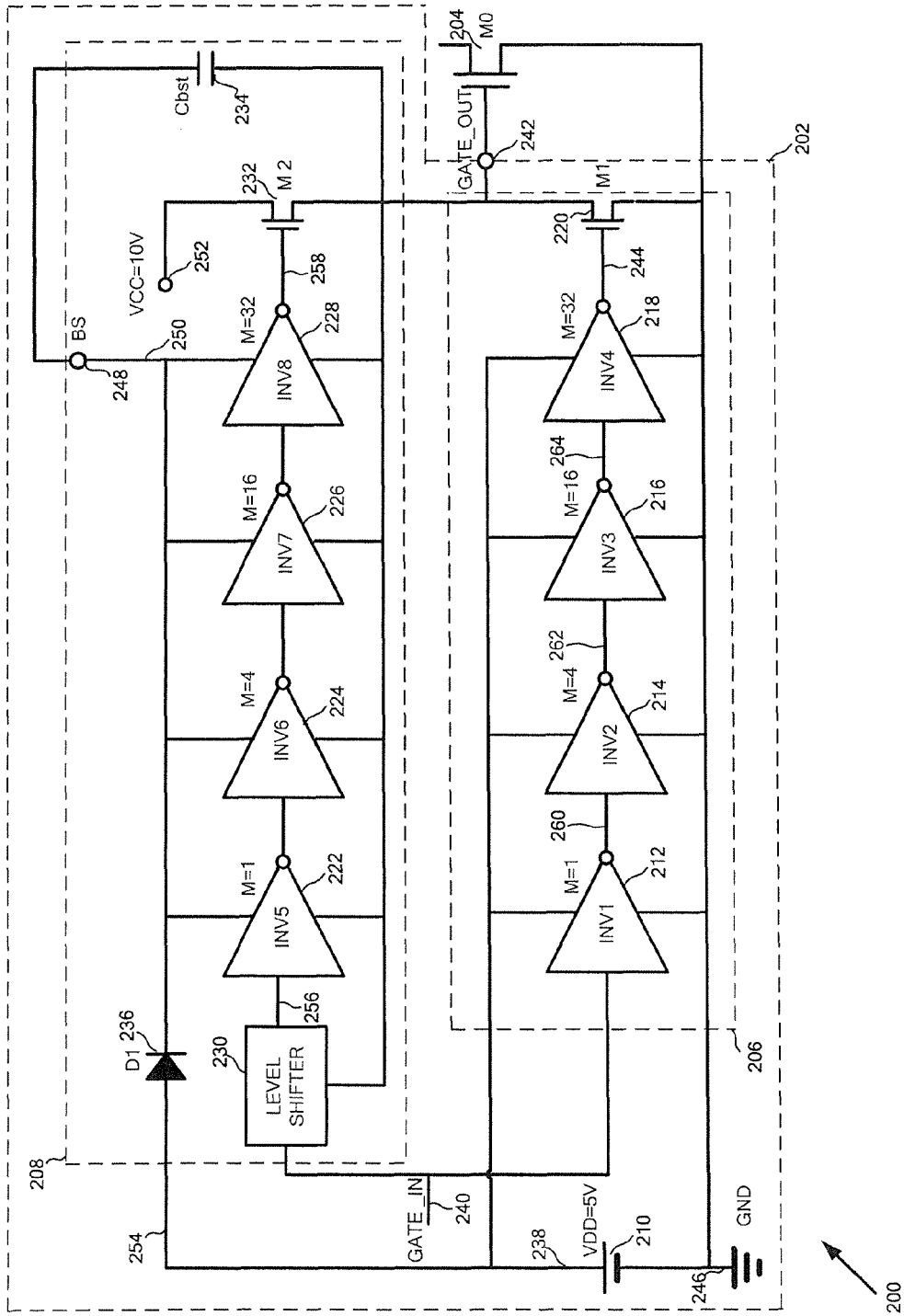
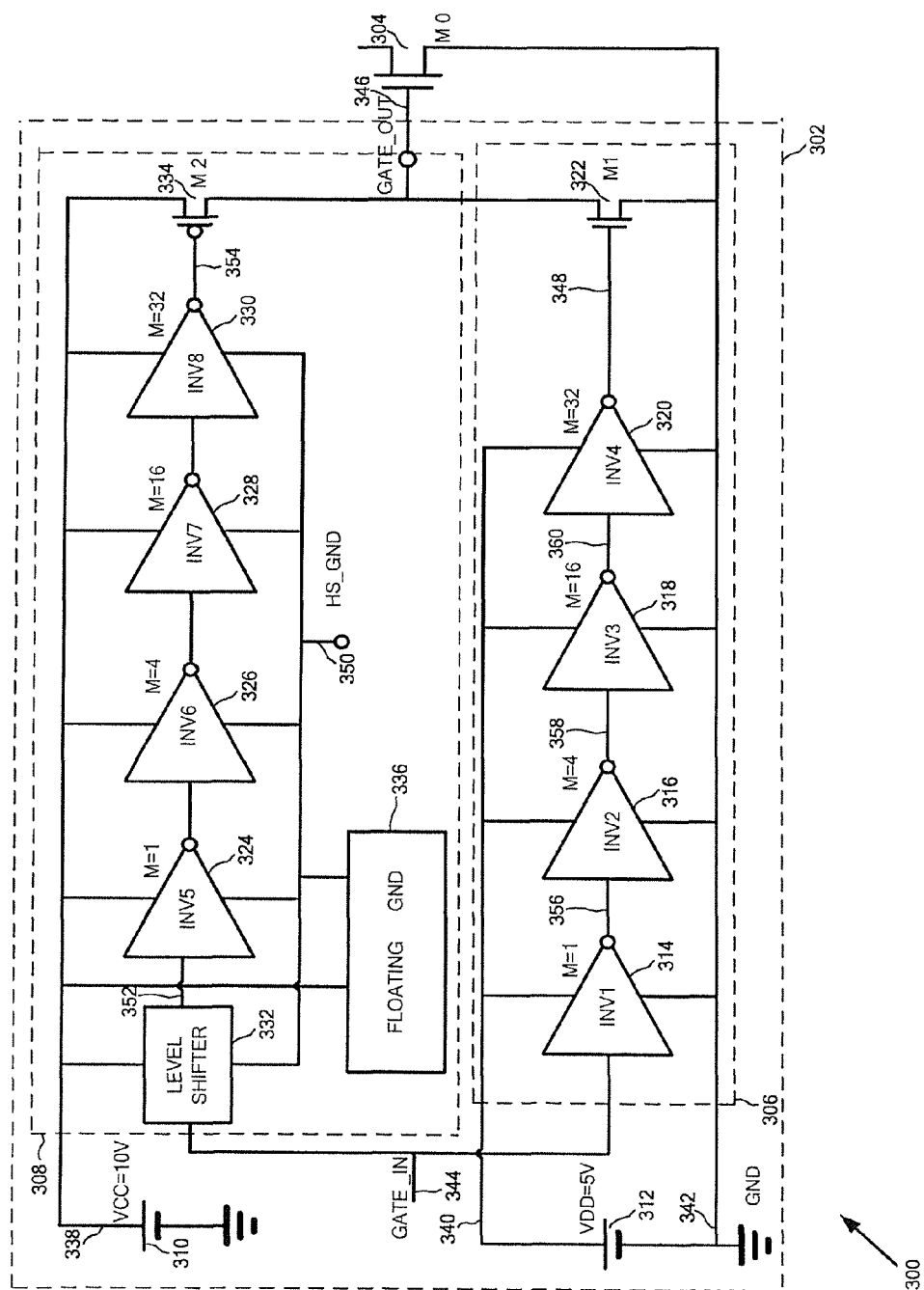


Figure 2  
(Prior Art)



**Figure 3**

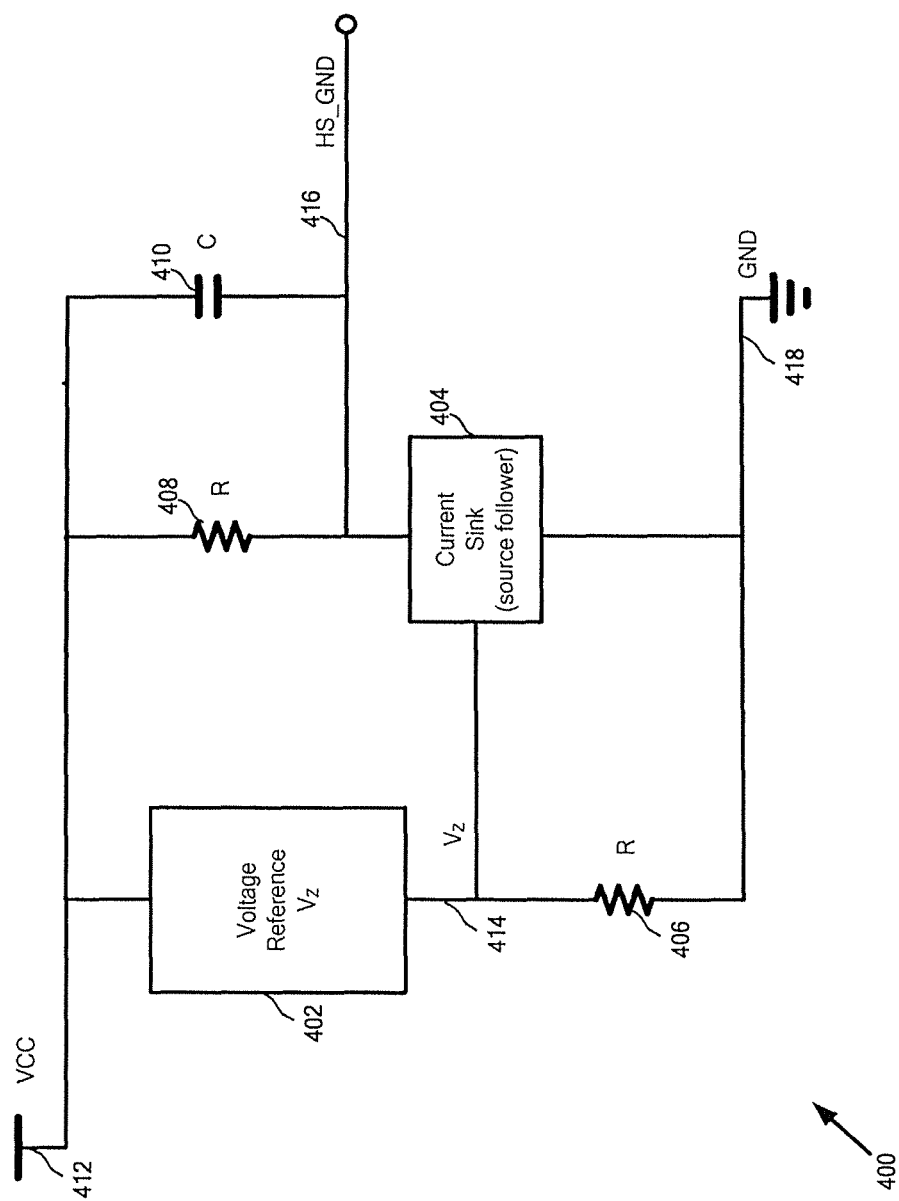
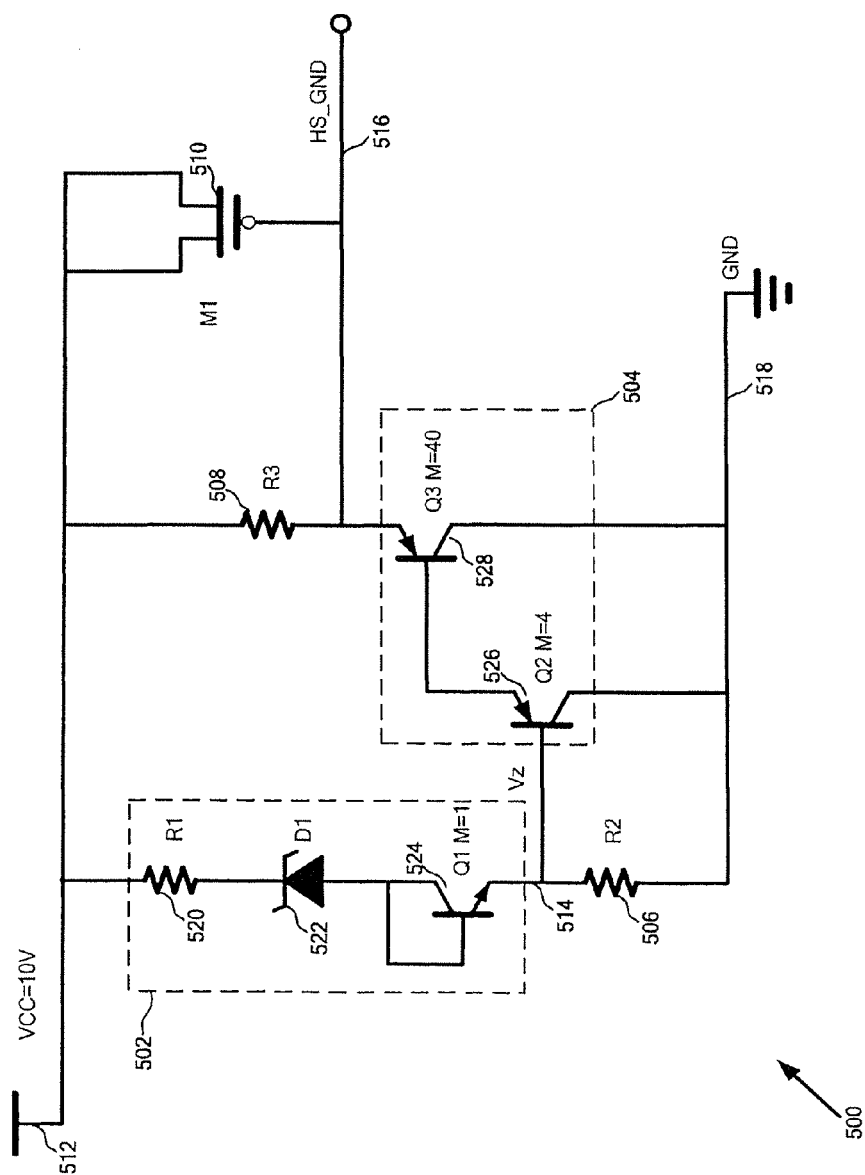


Figure 4



**Figure 5**

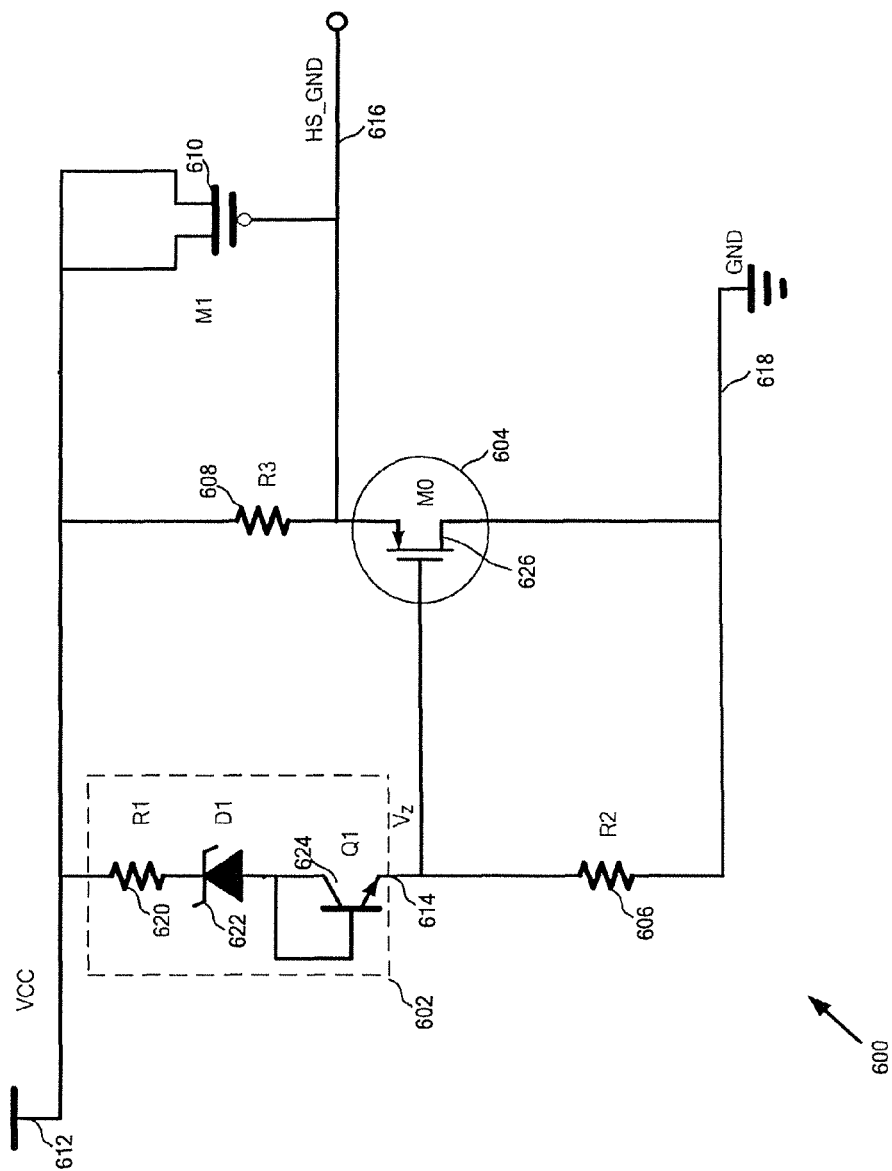


Figure 6

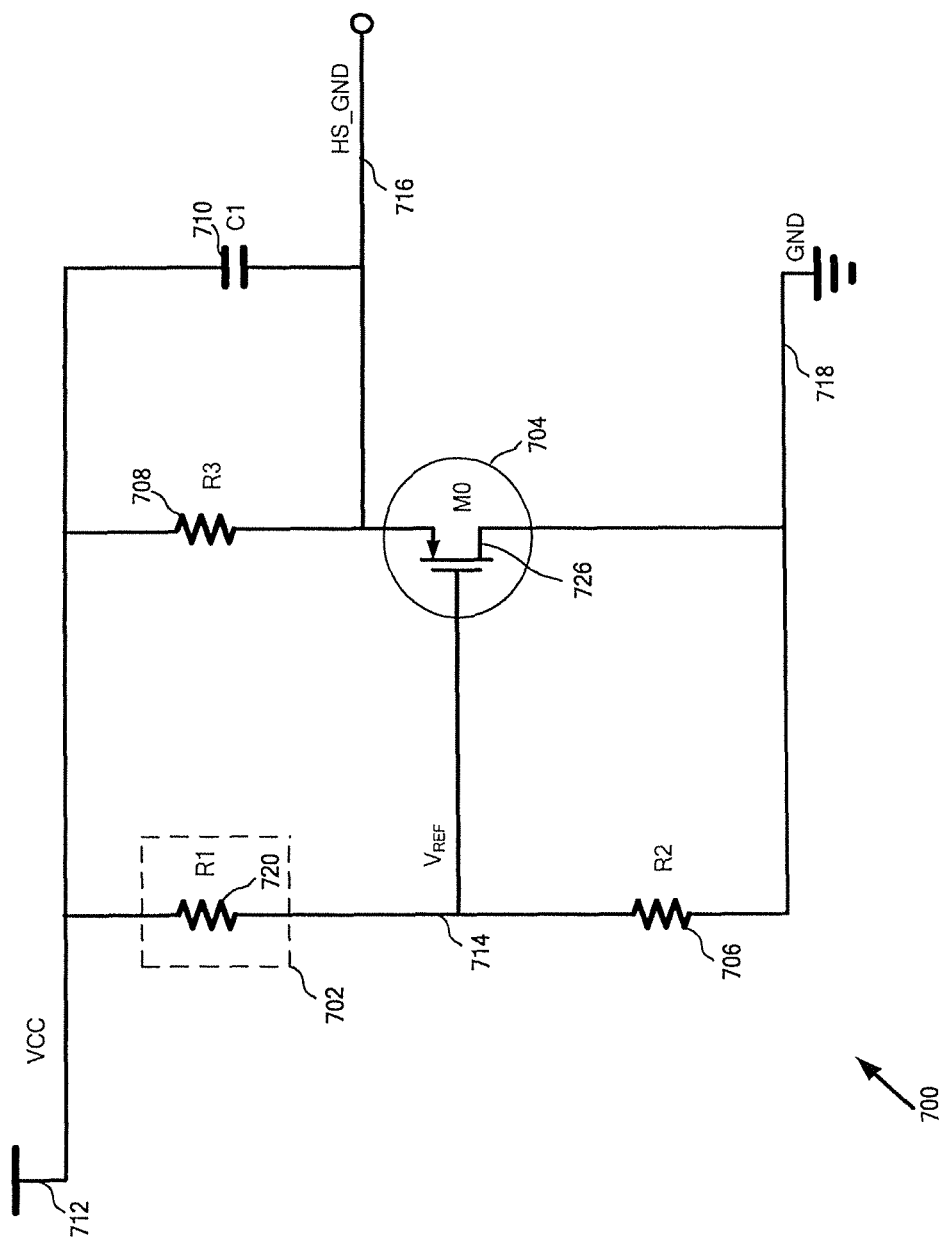


Figure 7



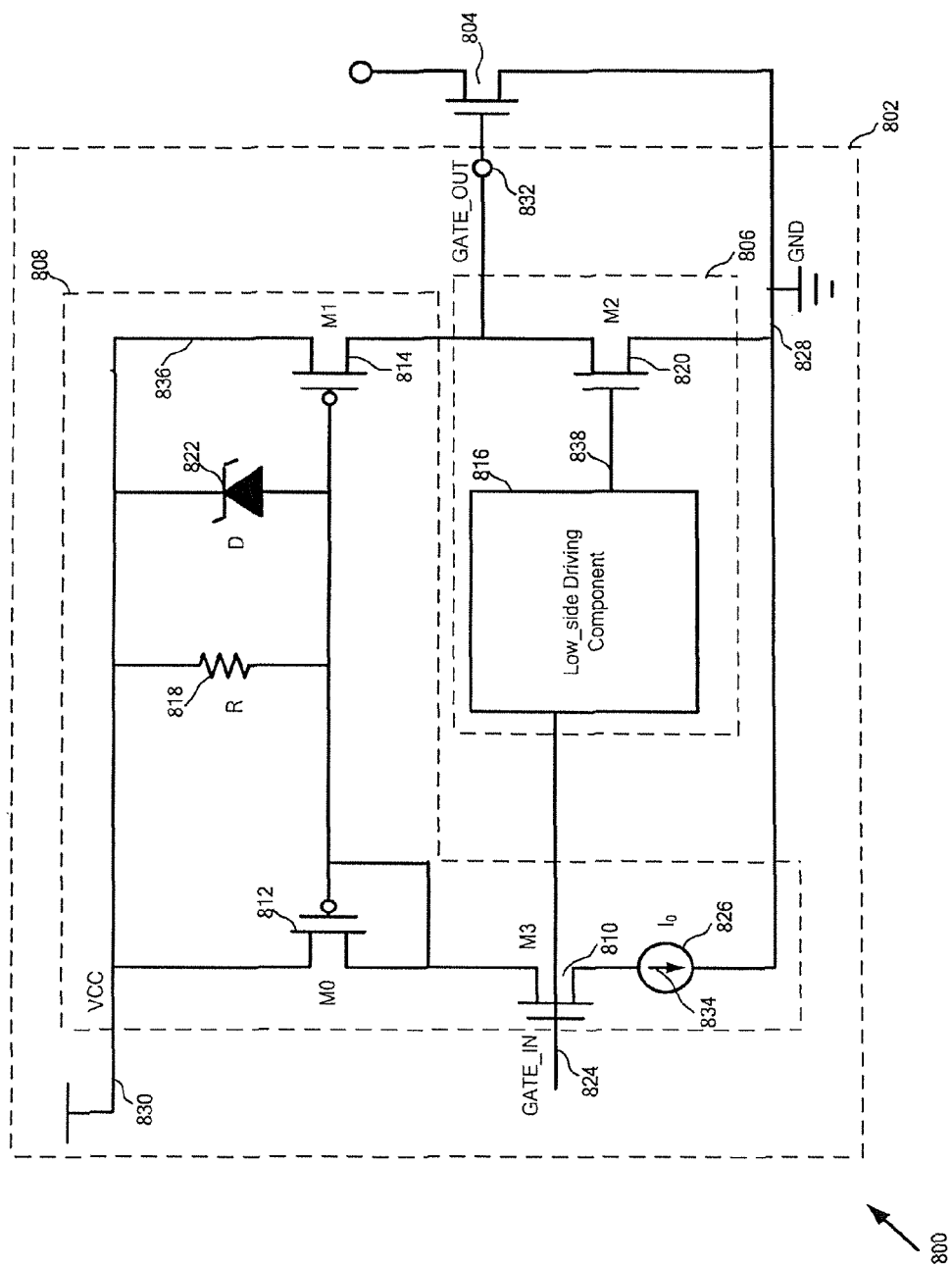


Figure 8

## SYSTEMS AND METHODS FOR DRIVING TRANSISTORS WITH HIGH THRESHOLD VOLTAGES

### 1. CROSS-REFERENCES TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 13/297,085, filed Nov. 15, 2011, which claims priority to Chinese Patent Application No. 201110317087.1, filed Oct. 12, 2011, commonly assigned, both of the above-referenced applications being incorporated by reference herein for all purposes.

### 2. BACKGROUND OF THE INVENTION

The present invention is directed to integrated circuits. More particularly, the invention provides systems and methods for driving transistors. Merely by way of example, the invention has been applied for driving a transistor with a high threshold voltage. But it would be recognized that the invention has a much broader range of applicability.

In high voltage applications, a power field-effect transistor (FET) often should have a high drain-source breakdown voltage (e.g., >100 V). Such a power FET usually has a threshold voltage of 3-4 V. Using a gate driver with a low output voltage, for example, 5 V to drive the power FET often results in a high turn-on resistance or incomplete turn-on of the power FET. Hence, a gate driver with a relatively high output voltage that is larger than 5 V (e.g., the output voltage being 8-10 V) is often needed.

FIG. 1 is a simplified conventional diagram showing a system 100 for driving a transistor 104. The gate-driving system 100 includes a gate driver 102 and a transistor 104. The gate driver 102 includes a power source 122, and four inverters 124, 126, 128 and 130. The inverter 124 includes transistors 106 and 114 that are connected with each other, and the inverter 126 includes transistors 108 and 116 that are connected with each other. Additionally, the inverter 128 includes transistors 110 and 118 that are connected with each other, and the inverter 130 includes transistors 112 and 120 that are connected with each other. The four inverters 124, 126, 128 and 130 are connected in cascade. For example, the transistors 106, 108, 110, and 112 are P-channel FETs, and the transistors 114, 116, 118, and 120 are N-channel FETs. In another example, the transistor 104 is a power FET. The power source 122 provides a low-level bias voltage 132 (e.g., GND) and a high-level bias voltage 134 (e.g.,  $V_{DD}$ ) to each of the cascaded inverters 124, 126, 128 and 130.

An input signal 136 (e.g., GATE\_IN) is received by the cascaded inverters 124, 126, 128 and 130, and in response the gate driver 102 generates an output signal 138 to drive the transistor 104. Specifically, in operation, the inverter 124 receives the input signal 136 (e.g., GATE\_IN), and generates a first inverted signal 140. The inverter 126 receives the first inverted signal 140, and generates a second inverted signal 142 which is received by the inverter 128. The inverter 128 then generates a third inverted signal 144 which is received by the inverter 130. The inverter 130 finally generates the output signal 138 for driving the transistor 104. For example, if the input signal 136 is at a logic high level, the transistor 106 is turned off and the transistor 114 is turned on. Then the first inverted signal 140 is generated to be approximately equal to the low-level bias voltage 132 (e.g., GND). The inverter 126 receives the first inverted signal 140, and the transistor 108 is turned on while the transistor 116 is turned off. The second inverted signal 142 is generated to be approximately equal to

the high-level bias voltage 134 (e.g.,  $V_{DD}$ ). In turn, the third inverted signal 144 is approximately equal to the low-level bias voltage 132 (e.g., GND), and the output signal 138 is approximately equal to the high-level bias voltage 134 (e.g.,  $V_{DD}$ ). Then, the transistor 104 is turned on by the output signal 138 if the transistor 104 is an N-channel FET. In another example, when the input signal 136 is at a logic low level, then the transistor 104 is turned off by the output signal 138 if the transistor 104 is an N-channel FET.

Usually, the transistors in the gate driver 102 (e.g., the transistor 106, etc.) are high voltage devices of which manufacturing costs are often high. Further, these transistors usually have high turn-on resistance, and low driving capability per unit area. Hence, to drive a same load, the transistors in the gate driver 102 often use larger areas than low voltage devices.

To improve the driving capability per unit area, a bootstrap structure and low voltage devices are often used in a gate driver. FIG. 2 is a simplified conventional diagram showing a system 200 with a bootstrap structure for driving a transistor 204. The gate-driving system 200 includes a gate driver 202 and a transistor 204. The gate driver 202 includes a low-side driver 206, a high-side driver 208, and a power source 210. The gate driver 202 further includes a bootstrap terminal 248 (e.g., BS). The low-side driver 206 includes the inverters 212, 214, 216 and 218, and a transistor 220. The high-side driver 208 includes the inverters 222, 224, 226 and 228, a level shifter 230, a transistor 232, a boost capacitor 234, and a diode 236. The inverters 212, 214, 216 and 218 are connected in cascade, and the inverters 222, 224, 226 and 228 are connected in cascade. For example, the transistors 220 and 232 are lateral-diffused MOSFETs (LDMOSs), such as lateral-diffused N-channel MOSFETs. In another example, the transistor 204 is a power FET.

The power source 210 provides a high-level bias voltage 238 (e.g.,  $V_{DD}$ ) and a low-level bias voltage 246 (e.g., GND) to each of the inverters in the low-side driver 206. An input signal 240 (e.g., GATE\_IN) is provided to both the low-side driver 206, and the high-side driver 208, and the gate driver 202 generates in response an output signal 242 to drive the transistor 204. Specifically, in operation, in the low-side driver 206, the inverter 212 receives the input signal 240 (e.g., GATE\_IN), and generates a first inverted signal 260. The inverter 214 receives the first inverted signal 260, and generates a second inverted signal 262 which is received by the inverter 216. The inverter 216 then generates a third inverted signal 264 which is received by the inverter 218. The inverter 218 generates a signal 244 to drive the transistor 220. If the transistor 220 is turned on by the signal 244 while the transistor 232 is off, then the output signal 242 (e.g., GATE\_OUT) becomes approximately equal to the low-level bias voltage 246 (e.g., GND). For example, the high-level bias voltage 238 (e.g.,  $V_{DD}$ ) is 5 V.

On the other hand, the input signal 240 is also received by the level shifter 230, and in response the level shifter 230 generates a signal 256. The cascaded inverters 222, 224, 226 and 228 receive the signal 256, and generate a signal 258 to drive the transistor 232. A high-level bias voltage 252 (e.g.,  $V_{CC}$ ) is provided to the transistor 232. If the transistor 232 is turned on by the signal 258 while the transistor 220 is off, then the output signal 242 (e.g., GATE\_OUT) becomes approximately equal to the high-level bias voltage 252 (e.g.,  $V_{CC}$ ). For example, the bias voltage 252 (e.g.,  $V_{CC}$ ) is 10 V.

The boost capacitor 234 operates to increase the voltage of the bootstrap terminal 248 (e.g., BS) to be larger in magnitude than the output signal 242 (e.g., GATE\_OUT) by a predetermined voltage, and to provide a voltage 250 for the high-side

driver 208 to operate. The diode 236 operates to rectify a current 254 flowing from the power source 210 to the diode 236 in order to prevent a current flowing from the high-side driver 208 to the power source 210 if the voltage of the bootstrap terminal 248 (e.g., BS) becomes larger than the bias voltage 238 (e.g.,  $V_{DD}$ ) provided by the power source 210.

The conventional gate driver 202 usually uses a bootstrap structure including the boost capacitor 234 and the bootstrap terminal 248 (e.g., BS) to provide a proper operating voltage for the high-side driver 208. However, the boost capacitor 234 often has a capacitance of tens or hundreds of nanofarads, and hence may not be easily incorporated into an integrated-circuit (IC) chip. Further, the bootstrap terminal 248 is not suitable if terminals (e.g., pins) are limited on an IC chip. Additionally, the diode 236 is usually needed for the gate driver 202 for rectifying the current 254. If the diode 236 is a Schottky diode which often has good performance for rectification, manufacturing costs may increase.

Hence it is highly desirable to improve techniques of driving transistors with high threshold voltages.

### 3. BRIEF SUMMARY OF THE INVENTION

The present invention is directed to integrated circuits. More particularly, the invention provides systems and methods for driving transistors. Merely by way of example, the invention has been applied for driving a transistor with a high threshold voltage. But it would be recognized that the invention has a much broader range of applicability.

According to one embodiment, a system for driving a transistor includes a floating-voltage generator, a first driving circuit, and a second driving circuit. The floating-voltage generator is configured to receive a first bias voltage and generate a floating voltage, the floating-voltage generator being further configured to change the floating voltage if the first bias voltage changes and to maintain the floating voltage to be lower than the first bias voltage by a first predetermined value in magnitude. The first driving circuit is configured to receive an input signal, the first bias voltage and the floating voltage. The second driving circuit is configured to receive the input signal, a second bias voltage and a third bias voltage, the first driving circuit and the second driving circuit being configured to generate an output signal to drive a transistor. Additionally, the first driving circuit includes a first driving transistor, the first driving transistor being configured to receive the first bias voltage and a first gate signal, the first gate signal being associated with at least the input signal, the first bias voltage, and the floating voltage. The second driving circuit includes a second driving transistor, the second driving transistor being configured to receive the third bias voltage and a second gate signal, the second gate signal being associated with at least the input signal, the second bias voltage, and the third bias voltage. The first driving transistor and the second driving transistor are further configured to generate the output signal. Moreover, if the first driving transistor is turned on by the first gate signal, the second driving transistor is turned off by the second gate signal. If the first driving transistor is turned off by the first gate signal, the second driving transistor is turned on by the second gate signal.

According to another embodiment, a method for driving a transistor includes receiving a first bias voltage, processing information associated with the first bias voltage, and generating a floating voltage based on at least information associated with the first bias voltage. The method further includes receiving an input signal, the first bias voltage, a second bias voltage, a third bias voltage, and the floating voltage, processing information associated with the input signal, the first bias

voltage, the second bias voltage, the third bias voltage and the floating voltage, and generating an output signal to drive a transistor based on at least information associated with the input signal, the first bias voltage, the second bias voltage, the third bias voltage and the floating voltage. Additionally, the process for generating the floating voltage based on at least information associated with the first bias voltage includes: changing the floating voltage if the first bias voltage changes, and maintaining the floating voltage to be lower than the first bias voltage by a first predetermined value in magnitude.

According to yet another embodiment, a system for driving a transistor includes a first driving circuit and a second driving circuit. The first driving circuit is configured to receive an input signal, a first bias voltage and a second bias voltage, the first driving circuit including a current mirror circuit, a switch, and a current sink. The second driving circuit is configured to receive the input signal and the second bias voltage, the first driving circuit and the second driving circuit being configured to generate an output signal to drive a transistor. Additionally, the switch is configured to receive the input signal. The current sink is configured to generate a first current. The current mirror circuit is coupled to the current sink through the switch and configured to generate a second current based on the first current. Moreover, the output signal is generated based on at least information associated with the second current.

According to yet another embodiment, a method of driving a transistor includes receiving an input signal, a first bias voltage and a second bias voltage, processing information associated with the input signal, the first bias voltage and the second bias voltage, and generating a first current based on at least information associated with the input signal, the first bias voltage and the second bias voltage. The method further includes processing information associated with the first current, generating a second current based on at least information associated with the first current, and processing information associated with the second current. Additionally, the method includes generating an output signal to drive a transistor based on at least information associated with the second current. Moreover, the second current is proportional to the first current in magnitude.

Many benefits are achieved by way of the present invention over conventional techniques. Certain embodiments of the present invention use a low dropout regulator (LDO) that sinks currents to provide a proper operating voltage for driving a transistor, without using a conventional high-voltage-device gate-driving structure or a bootstrap structure. Some embodiments of the present invention provide a proper operating voltage for driving a transistor, without using a boost capacitor or a bootstrap terminal. Certain embodiments of the present invention use low-voltage devices to construct a gate-driving structure and provide a cost-effective solution for driving a transistor.

Depending upon embodiment, one or more benefits may be achieved. These benefits and various additional objects, features and advantages of the present invention can be fully appreciated with reference to the detailed description and accompanying drawings that follow.

### 4. BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a simplified conventional diagram showing a system for driving a transistor.

FIG. 2 is a simplified conventional diagram showing a system with a bootstrap structure for driving a transistor.

5

FIG. 3 is a simplified diagram showing a system for driving a transistor according to an embodiment of the present invention.

FIG. 4 is a simplified diagram showing a floating-ground component for generating a floating-ground signal according to an embodiment of the present invention.

FIG. 5 is a simplified diagram showing a floating-ground component for generating a floating-ground signal according to one embodiment of the present invention.

FIG. 6 is a simplified diagram showing a floating-ground component for generating a floating-ground signal according to another embodiment of the present invention.

FIG. 7 is a simplified diagram showing a floating-ground component for generating a floating-ground signal according to yet another embodiment of the present invention.

FIG. 8 is a simplified diagram showing a system for driving a transistor according to another embodiment of the present invention.

## 5. DETAILED DESCRIPTION OF THE INVENTION

The present invention is directed to integrated circuits. More particularly, the invention provides systems and methods for driving transistors. Merely by way of example, the invention has been applied for driving a transistor with a high threshold voltage. But it would be recognized that the invention has a much broader range of applicability.

FIG. 3 is a simplified diagram showing a system 300 for driving a transistor according to an embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications.

The gate-driving system 300 includes a gate driver 302 and a transistor 304. The gate driver 302 includes a low-side driver 306, a high-side driver 308, and two power sources 310 and 312. The low-side driver 306 includes the inverters 314, 316, 318 and 320, and a transistor 322. The high-side driver 308 includes the inverters 324, 326, 328 and 330, a level shifter 332, a transistor 334, and a floating-ground component 336. For example, the inverters 314, 316, 318 and 320 are connected in cascade. In another example, the inverters 324, 326, 328 and 330 are connected in cascade. In yet another example, the transistor 304 is a power FET. In yet another example, the transistor 322 is an N-channel FET. In yet another example, the transistor 334 is a P-channel FET.

According to one embodiment, the power source 312 provides a high-level bias voltage 340 (e.g.,  $V_{DD}$ ) and a low-level bias voltage 342 (e.g., GND) to the low-side driver 306. For example, the power source 310 provides a high-level bias voltage 338 (e.g.,  $V_{CC}$ ) to the high-side driver 308. In another example, the high-level bias voltage 340 (e.g.,  $V_{DD}$ ) is 5 V. In yet another example, the high-level bias voltage 338 (e.g.,  $V_{CC}$ ) is 10 V.

According to another embodiment, an input signal 344 (e.g., GATE\_IN) is provided to both the low-side driver 306, and the high-side driver 308. For example, in response, the gate driver 302 generates an output signal 346 (e.g., GATE\_OUT) for driving the transistor 304. In another example, in operation, in the low-side driver 306, the inverter 314 receives the input signal 344 (e.g., GATE\_IN), and generates a first inverted signal 356. In yet another example, the inverter 316 receives the first inverted signal 356, and generates a second inverted signal 358 which is received by the inverter 318. In yet another example, the inverter 318 then generates a third inverted signal 360 which is received by the inverter 320. In

6

yet another example, the inverter 320 generates a signal 348 to drive the transistor 322. In yet another example, if the transistor 334 in the high-side driver 308 is turned off, the transistor 322 is turned on by the signal 348. In yet another example, the output signal 346 (e.g., GATE\_OUT) becomes approximately equal to the low-level bias voltage 342 (e.g., GND).

According to yet another embodiment, the level shifter 332 receives the input signal 344 (e.g., GATE\_IN), and in response generates a signal 352. For example, the cascaded inverters 324, 326, 328 and 330 receive the signal 352, and generate a signal 354 to drive the transistor 334. In another example, if the transistor 322 is turned off by the signal 348, the transistor 334 is turned on by the signal 354. In yet another example, the output signal 346 (e.g., GATE\_OUT) becomes approximately equal to the high-level bias voltage 338 (e.g.,  $V_{CC}$ ).

According to yet another embodiment, the floating-ground component 336 receives the high-level bias voltage 338 (e.g.,  $V_{CC}$ ), and in response generates a floating-ground signal 350 (e.g., HS\_GND). For example, the floating-ground component 336 automatically tracks the high-level bias voltage 338 (e.g.,  $V_{CC}$ ) to generate the floating-ground signal 350 (e.g., HS\_GND). In another example, if the high-level bias voltage 338 (e.g.,  $V_{CC}$ ) changes continuously in magnitude, the floating-ground component 336 automatically changes the floating-ground signal 350 (e.g., HS\_GND) continuously in magnitude to follow the high-level bias voltage 338 (e.g.,  $V_{CC}$ ). In yet another example, the floating-ground signal 350 (e.g., HS\_GND) is maintained to be lower in magnitude than the high-level bias voltage 338 (e.g.,  $V_{CC}$ ) by a predetermined voltage  $V_0$ . In another example, the floating-ground signal 350 (e.g., HS\_GND) is provided as a bias voltage to the cascaded inverters 324, 326, 328 and 330, and the level shifter 332. In yet another example, the operating voltage of the high-side driver 308 is no larger than the difference between the high-level bias voltage 338 (e.g.,  $V_{CC}$ ) and the floating-ground signal 350 (e.g., HS\_GND), e.g., the predetermined voltage  $V_0$ . In yet another example, the predetermined voltage  $V_0$  is 5 V.

FIG. 4 is a simplified diagram showing a floating-ground component 400 for generating a floating-ground signal according to an embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. The floating-ground component 400 includes a reference-voltage generator 402, a current sink 404, two resistors 406 and 408, and a capacitor 410. For example, the floating-ground component 400 is the same as the floating-ground component 336 as part of the gate-driving system 300.

According to one embodiment, the resistor 408 and the capacitor 410 are coupled with each other in parallel. For example, the resistor 408 and the capacitor 410 are coupled to the current sink 404 and the reference-voltage generator 402. In another example, the resistor 406 is coupled to the reference-voltage generator 402 and the current sink 404. In yet another example, the current sink 404 is a source follower. In yet another example, the current sink 404 is an emitter follower.

According to another embodiment, a high-level bias voltage 412 (e.g.,  $V_{CC}$ ) is provided to the reference-voltage generator 402, the resistor 408 and the capacitor 410. For example, the reference-voltage generator 402 in response generates a reference voltage signal 414 (e.g.,  $V_Z$ ). In another example, the reference-voltage generator 402 changes the reference voltage signal 414 (e.g.,  $V_Z$ ) if the high-level bias

voltage **412** (e.g.,  $V_{CC}$ ) changes. In yet another example, the resistor **406** and the current sink **404** receive the reference voltage signal **414** (e.g.,  $V_Z$ ). In yet another example, the current sink **404** and the resistor **406** also receive a low-level bias voltage **418** (e.g., GND). In yet another example, a floating-ground signal **416** (e.g., HS\_GND) is generated by the floating-ground component **400**. In yet another example, the difference between the high-level bias voltage **412** (e.g.,  $V_{CC}$ ) and the floating-ground signal **416** (e.g., HS\_GND) can be kept no larger than a predetermined voltage  $V_1$  by properly adjusting the reference voltage signal **414** (e.g.,  $V_Z$ ) and the voltage of the current sink **404**. In yet another example, the floating-ground signal **416** (e.g., HS\_GND) is lower than the high-level bias voltage **412** (e.g.,  $V_{CC}$ ). In yet another example, the floating-ground signal **416** (e.g., HS\_GND) is the same as the floating-ground signal **350**. In yet another example, the current sink **404** (e.g., a source follower or an emitter follower) operates together with the resistor **408** for sinking currents and keeping the magnitude of the floating-ground signal **416** (e.g., HS\_GND) approximately at a desired level. In yet another example, the high-level bias voltage **412** (e.g.,  $V_{CC}$ ) is 10 V. In yet another example, the predetermined voltage  $V_1$  is 5 V. In yet another example, the reference voltage signal **414** (e.g.,  $V_Z$ ) is maintained to be lower than the high-level bias voltage **412** (e.g.,  $V_{CC}$ ) by a predetermined value  $V_r$  in magnitude. In yet another example, the predetermined value  $V_r$  is different from the predetermined voltage  $V_1$ .

FIG. 5 is a simplified diagram showing a floating-ground component **500** for generating a floating-ground signal according to one embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications.

The floating-ground component **500** includes a reference-voltage generator **502**, a current sink **504**, two resistors **506** and **508**, and a transistor **510**. The reference-voltage generator **502** includes a resistor **520**, a diode **522**, and a transistor **524**. The current sink **504** includes two transistors **526** and **528**. For example, the floating-ground component **500** is the same as the floating-ground component **336** as part of the gate-driving system **300**. In another example, the floating-ground component **500** is the same as the floating-ground component **400**. In yet another example, the diode **522** is a Zener diode. In yet another example, the transistor **524** is an N-P-N bipolar junction transistor (BJT). In yet another example, the transistors **526** and **528** are Darlington-connected P-N-P BJTs. In yet another example, the transistor **510** is a P-channel FET.

According to one embodiment, the source and drain of the transistor **510** are coupled together. For example, the resistor **508** and the transistor **510** are coupled with each other. In another example, the resistor **508** and the transistor **510** are coupled to the current sink **504** and the reference-voltage generator **502**. In yet another example, the resistor **506** is coupled to the reference-voltage generator **502** and the current sink **504**.

According to another embodiment, a high-level bias voltage **512** (e.g.,  $V_{CC}$ ) is provided to the reference-voltage generator **502**, the resistor **508** and the transistor **510**. For example, the reference-voltage generator **502** in response generates a reference voltage signal **514** (e.g.,  $V_Z$ ). In another example, the resistor **506** and the current sink **504** receive the reference voltage signal **514** (e.g.,  $V_Z$ ). In yet another example, the current sink **504** and the resistor **506** also receive a low-level bias voltage **518** (e.g., GND). In yet another example, a floating-ground signal **516** (e.g., HS\_GND) is

generated by the floating-ground component **500**. In yet another example, the difference between the high-level bias voltage **512** (e.g.,  $V_{CC}$ ) and the floating-ground signal **516** (e.g., HS\_GND) can be kept no larger than a predetermined voltage  $V_2$  by properly adjusting the reference voltage signal **514** (e.g.,  $V_Z$ ) and the voltage of the current sink **504**. In yet another example, the floating-ground signal **516** (e.g., HS\_GND) is lower than the high-level bias voltage **512** (e.g.,  $V_{CC}$ ). In yet another example, the floating-ground signal **516** (e.g., HS\_GND) is the same as the floating-ground signal **350** or the floating-ground signal **416**. In yet another example, the high-level bias voltage **512** (e.g.,  $V_{CC}$ ) is 10 V. In yet another example, the predetermined voltage  $V_2$  is 5 V.

According to yet another embodiment, the resistor **520** operates for adjusting the difference between the high-level bias voltage **512** (e.g.,  $V_{CC}$ ) and the floating-ground signal **516** (e.g., HS\_GND). For example, the transistors **526** and **528** operate together with the resistor **508** for sinking currents and keeping the magnitude of the floating-ground signal **516** (e.g., HS\_GND) approximately at a desired level. In another example, the transistor **510** operates as a capacitor to keep the difference between the high-level bias voltage **512** (e.g.,  $V_{CC}$ ) and the floating-ground signal **516** (e.g., HS\_GND) from changing significantly. In yet another example, the transistor **524** operates to reduce the effect of the base-emitter voltage of the transistor **526** on the floating-ground signal **516** (e.g., HS\_GND). In yet another example, the resistor **506** operates to provide a direct current path for the diode **522** and the transistor **526**.

According to yet another embodiment, the difference between the high-level bias voltage **512** (e.g.,  $V_{CC}$ ) and the floating-ground signal **516** (e.g., HS\_GND) can be determined based on the following equation:

$$V_{CC} - V_{HS\_GND} = I_b \times R_1 + V_{bk\_zener} + V_{BE1} - V_{BE2} - V_{BE3} \quad (\text{Equation 1})$$

where  $V_{CC}$  represents the high-level bias voltage **512**, and  $V_{HS\_GND}$  represents the floating-ground signal **516**. Additionally,  $I_b$  represents a reverse break-down current of the diode **522**,  $V_{bk\_zener}$  represents a reverse break-down voltage of the diode **522**, and  $R_1$  represents the resistance of the resistor **520**. Furthermore,  $V_{BE1}$  represents the base-emitter voltage of the transistor **524**,  $V_{BE2}$  represents the base-emitter voltage of the transistor **526**, and  $V_{BE3}$  represents the base-emitter voltage of the transistor **528**.

For example, according to Equation 1, the resistance of the resistor **520** (e.g.,  $R_1$ ) can be set properly based on certain device characteristics of the diode **522** (e.g., a particular relationship of the reverse break-down voltage and the reverse break-down current of the diode **522**) in order to keep the difference between the high-level bias voltage **512** and the floating-ground signal **516** no larger than the predetermined voltage  $V_2$ . In another example, the reverse break-down voltage of the diode **522** (e.g.,  $V_{bk\_zener}$ ) is equal to 6 V, the base-emitter voltage of the transistor **524** (e.g.,  $V_{BE1}$ ) and the base-emitter voltage of the transistor **526** (e.g.,  $V_{BE2}$ ) are both equal to the forward voltage of their respective diodes, for example, 0.65 V, and the base-emitter voltage of the transistor **528** (e.g.,  $V_{BE3}$ ) is equal to another forward voltage of its respective diode, for example, 0.8 V. Then, the difference between the high-level bias voltage **512** and the floating-ground signal **516** can be determined, according to Equation 1, to be equal to 5.2 V, according to certain embodiments. In another example, the resistance of the resistor **520** (e.g.,  $R_1$ ) can be adjusted properly to reduce the deviation of the floating-ground signal **516** caused by random manufacturing errors.

According to yet another embodiment, the transistors **526** and **528** are Darlington-connected P-N-P BJTs, and receive the voltage signal **514** (e.g.,  $V_Z$ ). For example, the transistors **526** and **528** operate together with the resistor **508** to form an emitter follower as a current sink.

FIG. 6 is a simplified diagram showing a floating-ground component **600** for generating a floating-ground signal according to another embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications.

The floating-ground component **600** includes a reference-voltage generator **602**, a current sink **604**, two resistors **606** and **608**, and a transistor **610**. The reference-voltage generator **602** includes a resistor **620**, a diode **622**, and a transistor **624**. The current sink **604** includes a transistor **626**. For example, the floating-ground component **600** is the same as the floating-ground component **336** as part of the gate-driving system **300**. In another example, the floating-ground component **600** is the same as the floating-ground component **400**. In yet another example, the diode **622** is a Zener diode. In yet another example, the transistor **624** is an N-P-N bipolar junction transistor (BJT). In yet another example, the transistor **626** is a P-channel FET. In yet another example, the transistor **610** is a P-channel FET.

According to one embodiment, the source and drain of the transistor **610** are coupled together. For example, the resistor **608** and the transistor **610** are coupled with each other. In another example, the resistor **608** and the transistor **610** are coupled to the current sink **604** and the reference-voltage generator **602**. In yet another example, the resistor **606** is coupled to the reference-voltage generator **602** and the current sink **604**.

According to another embodiment, a high-level bias voltage **612** (e.g.,  $V_{CC}$ ) is provided to the reference-voltage generator **602**, the resistor **608** and the transistor **610**. For example, the reference-voltage generator **602** in response generates a reference voltage signal **614** (e.g.,  $V_Z$ ). In another example, the resistor **606** and the current sink **604** receive the reference voltage signal **614** (e.g.,  $V_Z$ ). In yet another example, the current sink **604** and the resistor **606** also receive a low-level bias voltage **618** (e.g., GND). In yet another example, a floating-ground signal **616** (e.g., HS\_GND) is generated by the floating-ground component **600**. In yet another example, the difference between the high-level bias voltage **612** (e.g.,  $V_{CC}$ ) and the floating-ground signal **616** (e.g., HS\_GND) can be kept no larger than a predetermined voltage  $V_3$  by properly adjusting the reference voltage signal **614** (e.g.,  $V_Z$ ) and the voltage of the current sink **604**. In yet another example, the floating-ground signal **616** (e.g., HS\_GND) is lower than the high-level bias voltage **612** (e.g.,  $V_{CC}$ ). In yet another example, the floating-ground signal **616** (e.g., HS\_GND) is the same as the floating-ground signal **350** or the floating-ground signal **416**. In yet another example, the high-level bias voltage **612** (e.g.,  $V_{CC}$ ) is 10 V. In yet another example, the predetermined voltage  $V_3$  is 5 V.

According to yet another embodiment, the resistor **620** and the transistor **624** operate for adjusting the difference between the high-level bias voltage **612** (e.g.,  $V_{CC}$ ) and the floating-ground signal **616** (e.g., HS\_GND). For example, the transistor **626** operates together with the resistor **608** for sinking currents and keeping the magnitude of the floating-ground signal **616** (e.g., HS\_GND) approximately at a desired level. In another example, the transistor **610** operates as a capacitor to keep the difference between the high-level bias voltage **612** (e.g.,  $V_{CC}$ ) and the floating-ground signal **616** (e.g.,

HS\_GND) from changing significantly. In yet another example, the transistor **626** receives the voltage signal **614** (e.g.,  $V_Z$ ), and operates together with the resistor **608** to form a source follower as a current sink.

FIG. 7 is a simplified diagram showing a floating-ground component **700** for generating a floating-ground signal according to yet another embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications.

The floating-ground component **700** includes a reference-voltage generator **702**, a current sink **704**, two resistors **706** and **708**, and a capacitor **710**. The reference-voltage generator **702** includes a resistor **720**. The current sink **704** includes a transistor **726**. For example, the floating-ground component **700** is the same as the floating-ground component **336** as part of the gate-driving system **300**. In another example, the floating-ground component **700** is the same as the floating-ground component **400**. In yet another example, the transistor **726** is a P-channel FET.

According to one embodiment, the resistor **708** and the capacitor **710** are coupled with each other in parallel. In another example, the resistor **708** and the capacitor **710** are coupled to the current sink **704** and the reference-voltage generator **702**. In yet another example, the resistor **706** is coupled to the reference-voltage generator **702** and the current sink **704**.

According to another embodiment, a high-level bias voltage **712** (e.g.,  $V_{CC}$ ) is provided to the reference-voltage generator **702**, the resistor **708** and the capacitor **710**. For example, the reference-voltage generator **702** in response generates a reference voltage signal **714** (e.g.,  $V_{REF}$ ). In another example, if the high-level bias voltage **712** (e.g.,  $V_{CC}$ ) is constant in magnitude, the reference voltage signal **714** (e.g.,  $V_{REF}$ ) is generated based on the voltage division between the resistors **720** and **706**. In another example, the resistor **706** and the current sink **704** receive the reference voltage signal **714** (e.g.,  $V_{REF}$ ). In yet another example, the current sink **704** and the resistor **706** also receive a low-level bias voltage **718** (e.g., GND). In yet another example, a floating-ground signal **716** (e.g., HS\_GND) is generated by the floating-ground component **700**. In yet another example, the difference between the high-level bias voltage **712** (e.g.,  $V_{CC}$ ) and the floating-ground signal **716** (e.g., HS\_GND) can be kept no larger than a predetermined voltage  $V_4$  by properly adjusting the reference voltage signal **714** (e.g.,  $V_{REF}$ ) and the voltage of the current sink **704**. In yet another example, the floating-ground signal **716** (e.g., HS\_GND) is lower than the high-level bias voltage **712** (e.g.,  $V_{CC}$ ). In yet another example, the floating-ground signal **716** (e.g., HS\_GND) is the same as the floating-ground signal **350** or the floating-ground signal **416**. In yet another example, the high-level bias voltage **712** (e.g.,  $V_{CC}$ ) is 10 V. In yet another example, the predetermined voltage  $V_4$  is 5 V. In yet another example, the resistance of the resistors **720** and **706** can be adjusted in order to outputting the floating-ground signal **716** with a proper magnitude. In yet another example, the transistor **726** receives the voltage signal **714** and operates together with the resistor **708** to form a source follower as a current sink.

FIG. 8 is a simplified diagram showing a system **800** for driving a transistor according to another embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications.

11

The gate-driving system **800** includes a gate driver **802** and a transistor **804**. The gate driver **802** includes a low-side driver **806** and a high-side driver **808**. The low-side driver **806** includes a low-side driving component **816** and a transistor **820**. The high-side driver **808** includes two transistors **812** and **814**, a resistor **818**, a diode **822**, a switch **810** and a current sink **826**. For example, the diode **822** is a Zener diode. In another example, the transistors **812** and **814** are P-channel FETs, and are included in a current mirror circuit. In yet another example, the switch **810** is an N-channel FET. In yet another example, the transistor **820** is an N-channel FET. In yet another example, a low-level bias voltage **828** (e.g., GND) is provided to the low-side driver **806**. In yet another example, a high-level bias voltage **830** (e.g.,  $V_{CC}$ ) is provided to the high-side driver **808**. In yet another example, the bias voltage **830** (e.g.,  $V_{CC}$ ) is 10 V.

According to one embodiment, an input signal **824** (e.g., GATE\_IN) is provided to both the low-side driver **806** and the high-side driver **808**. For example, in response, the gate driver **802** generates an output signal **832** (e.g., GATE\_OUT) to drive the transistor **804**. In another example, in operation, the low-side driving component **816** receives the input signal **824** (e.g., GATE\_IN), and generates in response a signal **838** to drive the transistor **820**. In yet another example, if the input signal **824** (e.g., GATE\_IN) is at the logic high level, the signal **838** is at a logic low level, and the transistor **820** is turned off. In yet another example, the input signal **824** (e.g., GATE\_IN) is provided to the low-side driving component **816** directly, without going through the switch **810**.

According to another embodiment, the high-side driver **808** receives the input signal **824** (e.g., GATE\_IN) at the switch **810**. For example, if the input signal **824** (e.g., GATE\_IN) is at a logic high level, the switch **810** is closed (e.g., on). In yet another example, the current sink **826** generates a current **834** that flows through the switch **810** and the transistor **812**. In yet another example, the current **834** is mirrored by the transistor **814**, with a predetermined ratio, to generate a current **836** that flows through the transistor **814**. Hence, the output signal **832** increases in magnitude according to certain embodiments. For example, the current **834** and the physical properties of the transistors **812** and **814** can be adjusted properly to control the current **836**. In another example, the resistor **818** and the diode **822** operate to keep the transistors **812** and **814** functioning properly.

According to yet another embodiment, a system for driving a transistor includes a floating-voltage generator, a first driving circuit, and a second driving circuit. The floating-voltage generator is configured to receive a first bias voltage and generate a floating voltage, the floating-voltage generator being further configured to change the floating voltage if the first bias voltage changes and to maintain the floating voltage to be lower than the first bias voltage by a first predetermined value in magnitude. The first driving circuit is configured to receive an input signal, the first bias voltage and the floating voltage. The second driving circuit is configured to receive the input signal, a second bias voltage and a third bias voltage, the first driving circuit and the second driving circuit being configured to generate an output signal to drive a transistor. Additionally, the first driving circuit includes a first driving transistor, the first driving transistor being configured to receive the first bias voltage and a first gate signal, the first gate signal being associated with at least the input signal, the first bias voltage, and the floating voltage. The second driving circuit includes a second driving transistor, the second driving transistor being configured to receive the third bias voltage and a second gate signal, the second gate signal being associated with at least the input signal, the second bias voltage,

12

and the third bias voltage. The first driving transistor and the second driving transistor are further configured to generate the output signal. Moreover, if the first driving transistor is turned on by the first gate signal, the second driving transistor is turned off by the second gate signal. If the first driving transistor is turned off by the first gate signal, the second driving transistor is turned on by the second gate signal. For example, the system is implemented according to at least FIG. 3, FIG. 4, FIG. 5, FIG. 6, and/or FIG. 7.

In one embodiment, a method for driving a transistor includes receiving a first bias voltage, processing information associated with the first bias voltage, and generating a floating voltage based on at least information associated with the first bias voltage. The method further includes receiving an input signal, the first bias voltage, a second bias voltage, a third bias voltage, and the floating voltage, processing information associated with the input signal, the first bias voltage, the second bias voltage, the third bias voltage and the floating voltage, and generating an output signal to drive a transistor based on at least information associated with the input signal, the first bias voltage, the second bias voltage, the third bias voltage and the floating voltage. Additionally, the process for generating the floating voltage based on at least information associated with the first bias voltage includes: changing the floating voltage if the first bias voltage changes, and maintaining the floating voltage to be lower than the first bias voltage by a first predetermined value in magnitude. For example, the method is implemented according to at least FIG. 3, FIG. 4, FIG. 5, FIG. 6, and/or FIG. 7.

According to another embodiment, a system for driving a transistor includes a first driving circuit and a second driving circuit. The first driving circuit is configured to receive an input signal, a first bias voltage and a second bias voltage, the first driving circuit including a current mirror circuit, a switch, and a current sink. The second driving circuit is configured to receive the input signal and the second bias voltage, the first driving circuit and the second driving circuit being configured to generate an output signal to drive a transistor. Additionally, the switch is configured to receive the input signal. The current sink is configured to generate a first current. The current mirror circuit is coupled to the current sink through the switch and configured to generate a second current based on the first current. Moreover, the output signal is generated based on at least information associated with the second current. For example, the system is implemented according to at least FIG. 8.

According to yet another embodiment, a method of driving a transistor includes receiving an input signal, a first bias voltage and a second bias voltage, processing information associated with the input signal, the first bias voltage and the second bias voltage, and generating a first current based on at least information associated with the input signal, the first bias voltage and the second bias voltage. The method further includes processing information associated with the first current, generating a second current based on at least information associated with the first current, and processing information associated with the second current. Additionally, the method includes generating an output signal to drive a transistor based on at least information associated with the second current. Moreover, the second current is proportional to the first current in magnitude. For example, the method is implemented according to at least FIG. 8.

For example, some or all components of various embodiments of the present invention each are, individually and/or in combination with at least another component, implemented using one or more software components, one or more hardware components, and/or one or more combinations of soft-

## 13

ware and hardware components. In another example, some or all components of various embodiments of the present invention each are, individually and/or in combination with at least another component, implemented in one or more circuits, such as one or more analog circuits and/or one or more digital circuits. In yet another example, various embodiments and/or examples of the present invention can be combined.

Although specific embodiments of the present invention have been described, it will be understood by those of skill in the art that there are other embodiments that are equivalent to the described embodiments. Accordingly, it is to be understood that the invention is not to be limited by the specific illustrated embodiments, but only by the scope of the appended claims.

What is claimed is:

1. A system for driving a transistor, the system comprising:  
a floating-voltage generator configured to receive a first bias voltage and generate a floating voltage, the floating-voltage generator being further configured to change the floating voltage if the first bias voltage changes and to maintain the floating voltage to be lower than the first bias voltage by a first predetermined value in magnitude;  
a first driving circuit configured to receive an input signal, the first bias voltage and the floating voltage; and  
a second driving circuit configured to receive the input signal, a second bias voltage and a third bias voltage, the first driving circuit and the second driving circuit being configured to generate an output signal to drive a transistor;

wherein:

the first driving circuit includes a first driving transistor, the first driving transistor being configured to receive the first bias voltage and a first gate signal, the first gate signal being associated with at least the input signal, the first bias voltage, and the floating voltage;  
the second driving circuit includes a second driving transistor, the second driving transistor being configured to receive the third bias voltage and a second gate signal, the second gate signal being associated with at least the input signal, the second bias voltage, and the third bias voltage; and

the first driving transistor and the second driving transistor are further configured to generate the output signal;

wherein:

if the first driving transistor is turned on by the first gate signal, the second driving transistor is turned off by the second gate signal; and

if the first driving transistor is turned off by the first gate signal, the second driving transistor is turned on by the second gate signal.

2. The system of claim 1 wherein:

the floating-voltage generator includes a reference-voltage generator and a current sinking component;

wherein:

the reference-voltage generator is configured to receive the first bias voltage and generate a reference voltage; and  
the current sinking component is configured to receive the reference voltage and generate the floating voltage.

3. The system of claim 2 wherein the reference-voltage generator is further configured to change the reference voltage if the first bias voltage changes and to maintain the reference voltage to be lower than the first bias voltage by a second predetermined value in magnitude.

4. The system of claim 3 wherein the second predetermined value is different from the first predetermined value.

## 14

5. The system of claim 1 wherein the first driving circuit and the second driving circuit are further configured to change the output signal from the third bias voltage to the first bias voltage and from the first bias voltage to the third bias voltage.

6. The system of claim 1 wherein the third bias voltage is ground.

7. The system of claim 1 wherein the first driving transistor is a P-channel field effect transistor.

8. The system of claim 7 wherein the second driving transistor is an N-channel field effect transistor.

9. A method for driving a transistor, the method comprising:

receiving a first bias voltage;

processing information associated with the first bias voltage;

generating a floating voltage based on at least information associated with the first bias voltage;

receiving an input signal, the first bias voltage, a second bias voltage, a third bias voltage, and the floating voltage;

processing information associated with the input signal, the first bias voltage, the second bias voltage, the third bias voltage and the floating voltage; and

generating an output signal to drive a transistor based on at least information associated with the input signal, the first bias voltage, the second bias voltage, the third bias voltage and the floating voltage;

wherein the process for generating the floating voltage based on at least information associated with the first bias voltage includes:

changing the floating voltage if the first bias voltage changes; and

maintaining the floating voltage to be lower than the first bias voltage by a predetermined value in magnitude.

10. A method of driving a transistor, the method comprising:

receiving an input signal, a first bias voltage and a second bias voltage;

processing information associated with the input signal, the first bias voltage and the second bias voltage;

generating a first current based on at least information associated with the input signal, the first bias voltage and the second bias voltage;

processing information associated with the first current;

generating a second current based on at least information associated with the first current;

processing information associated with the second current; and

generating an output signal to drive a transistor based on at least information associated with the second current;

wherein:

the second current is proportional to the first current in magnitude.

11. The method of claim 10 wherein the process for generating an output signal to drive a transistor based on at least information associated with the second current includes:

changing the output signal from the second bias voltage to the first bias voltage; and

changing the output signal from the first bias voltage to the second bias voltage.

12. A system for driving a transistor, the system comprising:

a voltage generator configured to receive a first voltage and generate a second voltage, the voltage generator being



## 15

further configured to change the second voltage in response to the first voltage changing and to maintain the second voltage to be lower than the first voltage by a first predetermined value in magnitude;

a first drive circuit configured to receive an input signal, the first voltage and the second voltage; and

a second drive circuit configured to receive the input signal, a third voltage and a fourth voltage, the first drive circuit and the second drive circuit being configured to generate an output signal to drive a transistor;

wherein:

the first drive circuit includes a first driving transistor, the first driving transistor being configured to receive the first voltage and a first gate signal, the first gate signal being associated with at least the input signal, the first voltage, and the second voltage;

the second drive circuit includes a second driving transistor, the second driving transistor being configured to receive the fourth voltage and a second gate signal, the second gate signal being associated with at least the input signal, the third voltage, and the fourth voltage; and

the first driving transistor and the second driving transistor are further configured to generate the output signal;

wherein:

in response to the first driving transistor being turned on, the second driving transistor is configured to be turned off; and

in response to the first driving transistor being turned off, the second driving transistor is configured to be turned on.

## 16

13. The system of claim 12 wherein:

the voltage generator includes a reference generator configured to generate a reference voltage; and

the reference generator is further configured to change the reference voltage in response to the first voltage changing and to maintain the reference voltage to be lower than the first voltage by a second predetermined value in magnitude.

14. A method for driving a transistor, the method comprising:

receiving a first voltage;

processing information associated with the first voltage;

generating a second voltage based on at least information associated with the first voltage;

receiving an input signal, the first voltage, a third voltage, a fourth voltage, and the second voltage;

processing information associated with the input signal, the first voltage, the third voltage, the fourth voltage and the second voltage; and

generating an output signal to drive a transistor based on at least information associated with the input signal, the first voltage, the third voltage, the fourth voltage and the second voltage;

wherein the process for generating the second voltage based on at least information associated with the first voltage includes:

changing the second voltage in response to the first voltage changing; and

maintaining the second voltage to be lower than the first voltage by a predetermined value in magnitude.

\* \* \* \* \*